§4. Temperature Measurement of ICRF Antennas in LHD

Saito, K.

Hot spots were observed by CCD cameras during long pulse operation on two ICRF antennas (3.5U antenna and 7.5U antenna) in the same positions at the top of the left side protectors attached to the upper antennas. For the 7.5U antenna, an infrared (IR) camera was installed to measure the temperature of the antenna. Figure 1 shows the temperature distribution on the antenna measured by the IR camera. Without plasma (vacuum), this position was not heated. Additionally, in the case of discharge by NNBI only, this position was also not heated. The position of the hot spot was not shifted by changing magnetic field strengths of B_{ax}=1.375 T, 1.5 T, 2.5 T and 2.75 T. Therefore the position was independent of the position of the ion cyclotron resonance layer. The temperature increment of the hot spot was proportional to the RF input power from the antenna, as shown in Fig. 2a. In this experiment, the distance between the antenna and the LCFS Δ was 8 cm and the pulse width was 5 seconds. The line-averaged electron density was 0.7-1.0×$10^{19}$$m^{-3}$. The major radius and magnetic field strength on the axis were set at R_{ax}=3.55 m and B_{ax}=2.789 T, respectively. The input power from the other antennas was kept almost constant at approximately 500 kW. Therefore, the hot spot was heated by the antenna itself. Loading resistance indicates the strength of power coupling between antenna and plasma. The definition of the loading resistance R is

$$P = \frac{1}{2} R \left(\frac{V}{Z_0}\right)^2$$

where P is the net injected ICRF power, V is the maximum voltage in the coaxial transmission line, and Z_0 is the characteristic impedance of the line. The temperature of the hot spot and the loading resistance decreased with increasing distance Δ, as shown in Fig. 2b. In the long pulse discharges, a long distance was selected to decrease the temperature, though the loading resistance decreased. Figure 3 shows the time evolution of the temperature of the hot spot. The conditions of the two discharges were identical except for distance Δ. The line-averaged electron density was 0.7×$10^{19}$$m^{-3}$, and the major radius and magnetic field strength on the axis were set at R_{ax}=3.55m and B_{ax}=2.789 T, respectively. The input power of the 7.5U antenna was 250 kW. By changing the distance from 8 cm to 10 cm, the temperature rise was drastically mitigated. The longest plasma duration time with ICRF heating of 31 minutes and 45seconds was achieved by employing maximum Δs (13 cm for 3.5U, L antennas and 14 cm for 7.5U antenna).

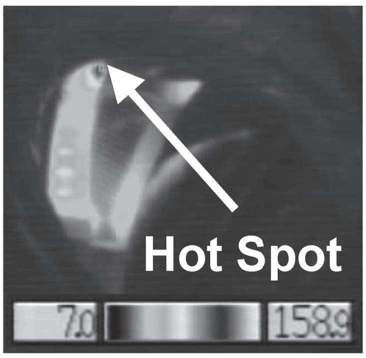

Fig. 1. Hot spot on 7.5U ICRF antenna

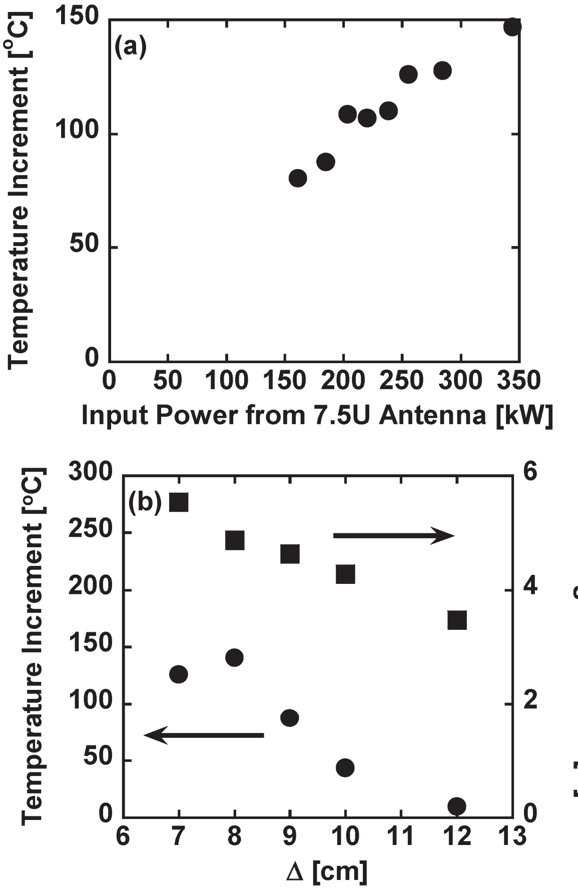

Fig. 2. Temperature increment depending on (a) input power and (b) distance between the antenna and the LCFS.

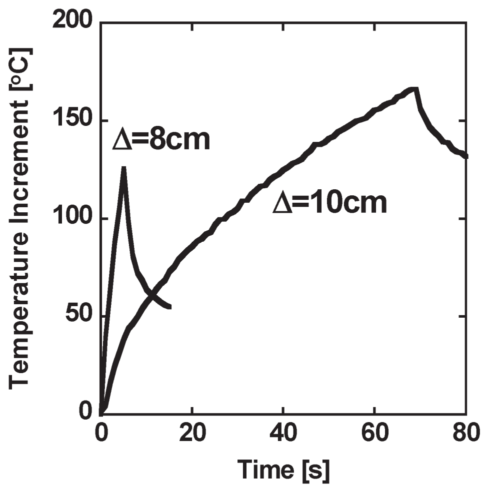

Fig. 3. Mitigation of hot spot temperature by the large distance between the antenna and the LCFS.